TRANSPORT CANADA

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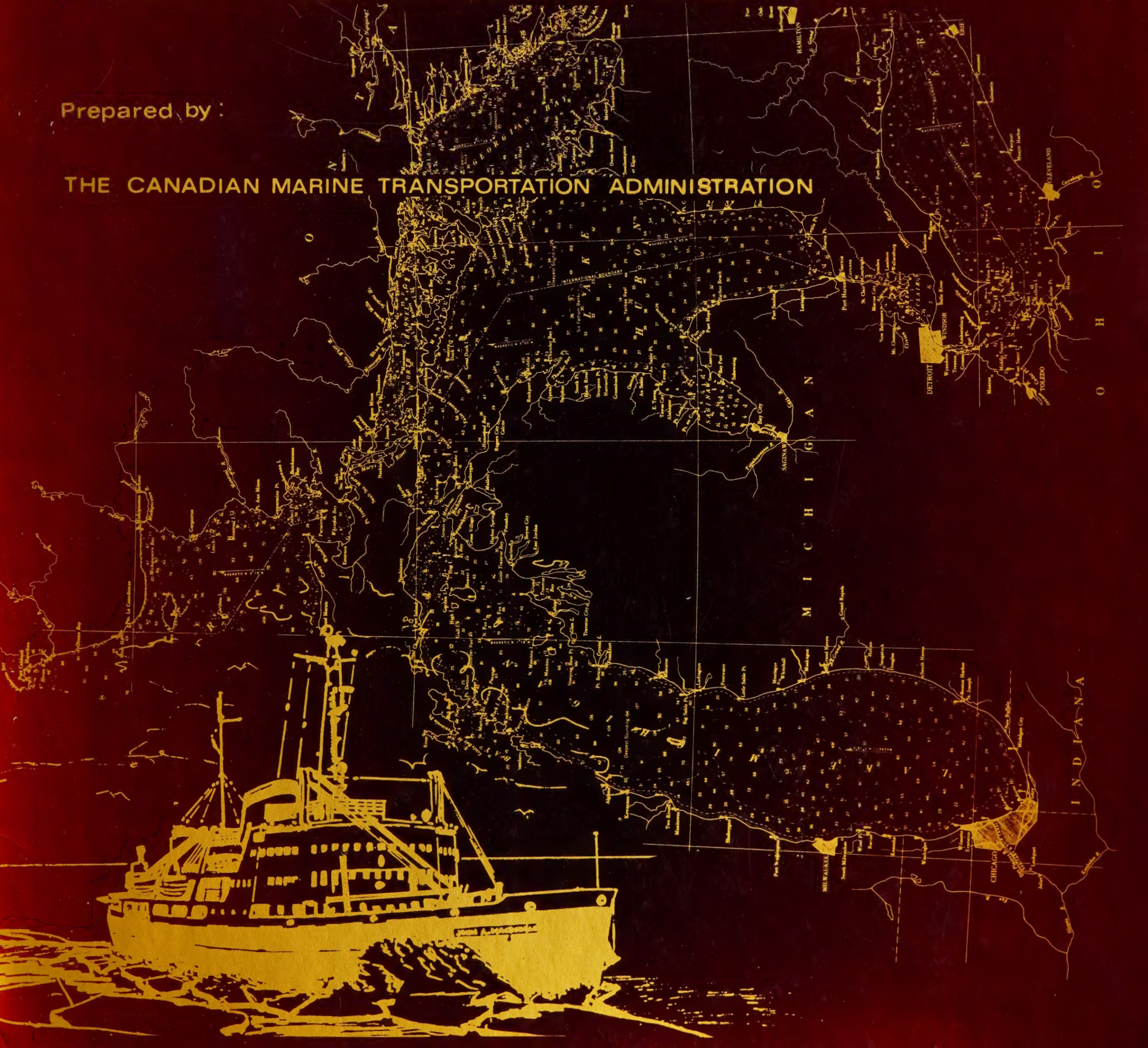
Ministry of Transport

EVOLUTION OF CANADIAN DEVELOPMENTS IN THE FIELD OF WINTER NAVIGATION ON THE ST. LAWRENCE RIVER AND GREAT LAKES

Prepared by:

THE CANADIAN MARINE TRANSPORTATION ADMINISTRATION



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MAY 10 - 11, 1971

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What is sometimes referred to as "*the ice mystique*" originated in the days when wind-powered wooden ships were almost routinely lost through being crushed by ice. One can readily appreciate the source of this mystique and the perils of ice navigation in those early days if one equates the size, hull strength, power and maneuverability of a modern ice-strengthened vessel to a vessel possessing characteristics similar to the *ketch NONSUCH*, a replica of which sailed through the Seaway in 1970.

An interesting account of how the crew of the *NONSUCH* solved the winter navigation problem is contained in "*The London Gazette*" of October 11, 1669 which published this brief notice upon the return of the *NONSUCH* to the Thames after having spent the winter in Canada (1668-69).

> *"This last night came in here the NONSUCH ketch which having endeavoured to make out a passage by the North-West, was in those seas environed with ice, which opposing her progress the men were forced to hale her on shoar and to provide against the ensuing cold of a long winter, which ending, they returned with a considerable quantity of Beaver, which made them some recompence for their cold confinement."*

In 1873 when Prince Edward Island entered confederation, one condition of membership was that the Dominion Government would guarantee a ferry connection to the impending railway system which would be opened in 1876. Although the other Maritime provinces had ice-free ports, Prince Edward Island could only be reached by crossing the Northumberland Straits where the ice during the winter was thick enough to be impassable for the steamers of the day. To meet this demand the Government built the first specially designed icebreaker, the *NORTHERN LIGHT* at Levis, Quebec in 1876. To the best of our knowledge this was the first such vessel built in the world. The continuing demand in successive years to provide the Prince Edward Island winter service had a significant influence on the development of a Canadian icebreaker fleet and the construction of passenger vessels able to navigate in ice.

Since that time there have been many developments which have significantly improved the performance of vessels in ice, and it is probably safe to say that the "*mystique*" is dying at an ever quickening pace. Vessels are now moving in impressive numbers through the gulf of the St. Lawrence and up the river to Montreal which is now considered to be virtually a year-round port.

The importance of an extension to the navigation season is illustrated by the fact that our Government has invested in excess of two billion dollars in the Great Lakes-St. Lawrence River Basin while the investment on related waterside developments dependent upon shipping has been several times this amount.

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I would therefore like to highlight some of the developments in winter navigation in the St. Lawrence River-Great Lakes system where Canada has devoted considerable resources towards either maintaining year-round navigation or an extension of the existing navigation season.

We shall trace these developments on a geographical basis starting here at the Gulf of St. Lawrence and proceeding into the Great Lakes, through the four main areas:

1. *from the Gulf of St. Lawrence to Montreal*
2. *the Montreal-Lake Ontario section of the Seaway*
3. *the Welland Canal section of the Seaway*
4. *the Great Lakes and in particular Lake Erie*

In addition, I shall briefly refer to the developments in the aids to navigation field as well as mention some aspects of the economics associated with any further extension of the Seaway system.

The evolutionary development of the Canadian Maritime winter trade is best illustrated in the first geographical area that I referred to. It is in the Gulf of St. Lawrence to Montreal sailing route that we can follow the development of the various generations of icebreakers.

Following the 1876 start with the NORTHERN LIGHT there were a succession of icebreakers designed specifically for the trade of the early 1900's. Typical of these were the EARL GREY, STANLEY and the MINTO. An interesting feature of the EARL GREY, which was built in England in 1909, is the fact that the vessel

continued in service following her sale to Russia in 1914 until the late nineteen fifties.

The second generation of icebreakers was constructed, starting in 1904, to cope with the ice jams in the St. Lawrence River and consisted of such ships as the *MONTCALM* and *CHAMPLAIN*. The *MONTCALM* was, at the time of commissioning, the largest and most powerful icebreaker in Canada, developing 3,600 horsepower and fitted with twin screws.

A series of steam reciprocating icebreakers followed the *MONTCALM* differing from each other in power and dimensions, but falling into the same general pre-war category. Among these vessels were the *N.B. MCLEAN* in 1930 and the *ERNEST LAPOINTE* in 1940, both of which are still in service upholding a tradition of toughness and longevity. In fact, as I am sure you are all aware, the *N.B. MCLEAN* was stationed in the area above Port Colborne during this past winter and played a significant role in assisting in getting this year's navigation season open as soon as it was, despite the exceptionally severe conditions. We shall have more to say on this later.

In the postwar period there was a revival in the construction of icebreakers and we saw the commissioning of the *d'IBERVILLE* in 1952, which incidentally was the first vessel to pass the St. Lambert Lock in April 1959; the transfer from the Department of National Defence of the *LABRADOR* in 1958; and in 1960 the addition of the *JOHN A. MACDONALD*. The *MACDONALD*, an ocean-going icebreaker of 15,000 shaft horsepower and 20,000 miles operating range, added considerable capability to the Canadian

fleet of icebreakers. You will recall she accompanied the *MANHATTAN* on its epic voyage. The construction of these vessels along with the *JOHN CABOT* and the *NORMAN MCLEOD ROGERS* could be considered as the emergence of the third generation of icebreakers normally referred to as the standard heavy icebreaker.

At the present time, we are moving into the fourth generation of icebreakers with the *LOUIS S. ST. LAURENT*. This vessel, with 13,000 tons displacement and 27,000 horsepower, is the largest non-nuclear icebreaker in the world. Like most of our heavy icebreaker fleet, it is used in the Gulf of St. Lawrence in winter and for arctic missions during the summer.

Virtually all seagoing ships used by the Coast Guard in Canadian waters are designed to operate to some extent in ice. There is attached to the back of the paper as PLATE No. 1 a list of the icebreakers used by the Canadian Coast Guard. In addition of course, there are other vessels such as search and rescue cutters, buoy tenders, supply ships, etc.

The operating costs of the icebreaker fleet for winter operation have been approximately $32 million over the past ten years. In 1960-61 the annual cost was $2.2 million, in 1964-65 $2.9 million and in 1969-70 $4.8 million. These increases are partly due to increased costs of salaries and materials, but also reflect the acquisition of four new icebreakers. It should be noted that these operating costs do not include any costs towards amortization on the initial costs of the vessel.

Perhaps at this point I should briefly outline the winter maritime operation and trade as we see it today.

The volume of winter cargo handled by vessels reporting to Ice Sydney rose from 0.7 million tons in 1959-60, to 7.5 million tons in 1964-65 and to 21 million tons in 1969-70; an increase of 20 million tons in one decade.

The main area of growth has been the development of the iron ore reserves in northern Quebec and the subsequent shipping trade from the Gulf ports of Sept Iles and Port Cartier. Along with this there has been a steady increase in the use of all St. Lawrence River ports up to and including Montreal which has the largest number of ship calls per season. The difference in cargo tonnage between this area and the iron ore ports is attributable to the difference in the size of ships using the two areas.

In the St. Lawrence River between Quebec and Montreal the winter cargo has increased from nil in 1959 to 1.9 million tons in 1964-65 and 4.3 million tons in 1969-70. The ice-strengthened *HELGA DAN* was the first foreign vessel to enter Quebec Harbour and thus introduce the era of commercial winter shipping in 1959. It is estimated that of this 4.3 million tons of cargo, 2.0 million tons can be considered to be a net increase in international cargo, which if it were not for winter navigation would not be available.

In order to support this traffic through the area and off the Eastern Seaboard, seventeen icebreakers are deployed from the area of the Lakehead to Cabot Strait during the winter months. The bulk of this force is concentrated in the Gulf for the support of shipping; the remainder is engaged in meeting the various responsibilities of flood control in the ship channel,

providing an open navigation channel up to Montreal, icebreaking in the Seaway and limited operation on the Great Lakes.

The service for the support of ships navigating in the ice congested waters is provided through the issuance of up-to-date information on ice conditions; advise on the best routes to follow; icebreaker support where available and considered necessary; and finally, the organization of convoys when conditions dictate. This service is provided from mid-December until ice clears in the spring from ice offices maintained at Sydney, Nova Scotia; St. John's, Newfoundland; and Montreal, Quebec.

Ice Central Halifax is the major collection and distribution point for ice information which is received via numerous communication systems from icebreakers, shore stations and aircraft. Throughout the winter, ice advisories and forecasts issued by the Ice Central Halifax are daily broadcast by radio and radio facsimile.

The support for the ice reconnaissance program is provided by the Meteorological Branch of the Ministry of Transport. The DC-4 Aircraft used in this service has a crew of seven plus five ice observers. The aircraft has been modified for ice observing and is equipped with remote sensing gear, closed circuit TV as well as additional marine radio and facsimile communication equipment. In addition to the fixed-wing aircraft, helicopters provide patrol capability in the more restricted waters of the St. Lawrence.

As you can appreciate the annual operating costs associated with this program are substantial and are conservatively estimated at $7 million.

In conjunction with this development of winter navigation in the lower St. Lawrence River, the Ministry has also experimented with and subsequently installed a number of other features in the channel. These installations again are installed to meet the dual challenge of reducing the danger of flooding and assisting winter navigation.

The first of these features was the installation of a system of floating wooden ice booms. These booms were initially established on an experimental basis; however, it is now considered that they are an essential feature of the ice control works of the ship channel. The system of booms, constructed in 500 ft. sections and consisting of British Columbia fir timbers 14 inches by 22 inches and 30 feet in length linked together with 2 inch diameter galvanized steel boom cable, has been designed to:

a) *accelerate the formation of a* ***stable*** *ice cover upstream of the boom;*

b) *reduce the movement of ice cover during its formation and thereby keep the channel clear;*

c) *minimize the erosion of the ice field by passing vessels and thus reduce the number of battures floating downstream presenting a hazard to shipping and the potential for causing a serious ice jam.*

The second feature was the construction of the Laprairie Basin Ice Control Structure which is located upstream of the *EXPO 67* site.

The development of the *EXPO 67* altered the St. Lawrence River regime. It was considered necessary that, in order to ensure

that more severe ice jams would not occur from a run of ice from upstream, a permanent type of ice control structure be built.

The ice structure is essentially an elaborate type of floating boom situated in an area of high river velocity. The ice boom was designed and constructed to quickly from an ice cover upstream should a severe ice jam occur in the river below Montreal. In practice, however, because of the icebreaker operation downstream, high water conditions seldom occur and the ice cover is restricted to two-thirds of the width of the river at this area. Experimental work is continuing with a "*second line of defence*" to improve the efficiency of the ice retention capacity of the structure by converting some stop logs to ice booms and floating them downstream.

The third feature was the articifial islands which were created downstream of Montreal in Lake St. Peter to assist in control of ice. The islands were constructed of glacial till from dredging operations and topped with rock. They were completed in 1968 and have performed as planned. The location of the three installations is shown on PLATE No. 2 and the details of the floating ice boom are shown on PLATE No. 3.

While these features have significantly assisted in improving the control of ice in the area, the cost has been high. The capital cost for the ice booms and artificial islands was roughly $1,000,000. and the capital cost for the Laprairie Basin structure was $18,000,000. The annual operating and maintenance cost for all three facilities is approximately $385,000.

With the introduction of these improvements combined with an effective icebreaker service, a comprehensive ice reconnaissance program and an extensive vessel information system such as exists at Montreal and Quebec City, it has been possible to make the shipping season on the lower St. Lawrence a year-round operation.

Throughout all of this an extensive research and development program has been carried out and is continuing in a number of areas such as:

- *a study of ice drift in the Gulf of St. Lawrence*
- *hydraulic model studies*
- *navigational systems*
- *aerial ice sensing*
- *icebreaker design*

Major ports located along the system have the main navigation channel running through their areas and this channel is kept open by the icebreakers. The approach channels and berths within Harbour limits are normally kept open by the use of ice-strengthened tugs.

I believe that this development of winter navigation up to Montreal represents the first phase in the extension of the navigation season into the Seaway and Great Lakes. It has been developed and financed by Canada and is being maintained at a conservatively estimated annual operating cost of $10,000,000.

The next phase in the extension of the system has been the improvements undertaken by the St. Lawrence Seaway Authority in the Montreal-Lake Ontario section of the system.

In 1959 when the Seaway was officially opened to navigation, the opening and closing dates for the navigation season were predicated on our experience in the handling of vessels in the old canals such as the Soulanges, Lachine and Cornwall. However as experience was gained with the new system, it became evident that it was necessary to consider the lengthening of the navigation season beyond the then normal period of April 15 to November 30. It was also evident that before any extension could be contemplated, it was necessary to "*firm up*" the system so that the trade could have reasonable assurance that whatever date was selected for the closing of the system, the date could be met even under severe weather conditions.

To meet this challenge, the Authority formed in 1964 an "*in-house*" group to examine, study, develop and report on the feasibility of meeting the stated objectives.

The committee reported early in their study that if the Authority wished to "*firm up*", especially the closing date for the system, then a program of construction was required for the South Shore Canal. The report was accepted and thus the first phase of extension was started in the Seaway.

The South Shore Canal is by geographical location the most northerly canal in the Montreal-Lake Ontario section of the Seaway. The seventeen mile canal and two locks, lifts vessels from Montreal, by-passing the Lachine rapids up to the level of Lake St. Louis.

The water temperatures in the canal normally reach the freezing point two to three weeks before Iroquois Lock which is 110 miles upstream. This is of course due to the fact that Lake Ontario is the source of heat for keeping water temperatures above the freezing point and as the outflow proceeds in a north-easterly direction down the river, the water is progressively chilled. The problem of cooling is accentuated by the low current velocity of the South Shore Canal with the result that the first severe ice problems start at St. Lambert Lock at the Montreal entrance to the Seaway.

To combat these typical canal ice problems, the Authority decided to undertake a program of construction on lock equipment improvement aimed at extending the capability of the canal to service vessels in severe weather conditions.

The phased 3.5 million dollar program which has just been completed this spring consisted of:

a) enlargement of the Regulating Works at Cote Ste. Catherine to increase the flow from 3,000 to 12,000 cfs and inject a supply of warmer water into the canal, the final design being based on the results of extensive hydraulic model studies;

b) installation of ice flushing systems at Cote Ste. Catherine and St. Lambert Locks for dispersal of ice through the system;

c) installation of air jets and bubbler systems to keep the gate recesses clear of ice and retard the formation of ice on lock gates;

d) *insulation of the lower lock gates combined with electric heating to reduce formation of ice on the gates;*

e) *construction of an ice diversion channel around St. Lambert Lock.*

In spite of these structural improvements it still is necessary to revert to age old manual operations such as steam jets, ice scrapers, ice lockages, etc., to combat ice.

With the completion of these projects, is is considered that the normal navigation season, in the Montreal-Lake Ontario area, should be roughly April 1 to mid-December. This statement presumes however an average Canadian winter with normal spring weather conditions - a condition that unfortunately did not exist during the spring of 1970 and even less so in 1971.

It must also be remembered that once every so many years nature will inevitably inflict an early severe freeze-up which unfortunately, cannot yet be predicted too far in advance with a high degree of accuracy.

Since this time of year is normally accompanied by periods of high winds, low visibility, snow storms, etc., the number of hours per day under which a vessel can navigate, are substantially reduced and the chances of trapping vessels in the system are enhanced. Under these conditions, owners and agents should be prepared on relatively short notice to evacuate their vessels from the system as quickly as possible.

The completion of these projects has also resulted in extending the operational season on the South Shore Canal roughly

to that permitted by nature on the balance of the Montreal-Lake Ontario section.

It is now considered that this marks the end of the first phase of season extension on the Seaway. This phase has seen the season officially extended to the Montreal-Lake Ontario section of the Seaway from 234 days in 1960 to approximately 260 days in 1970.

The next phase of any program to extend the season still more will require further developments in a number of interrelated areas. It is our opinion that improved methods of combatting ice formation at the end of the navigation season offer the best hope of a further extension, particularly in the light of our experience this spring and it is here that our efforts will be directed.

The next phase is presently in the policy development stage in Canada. It is considered that the program will have many areas requiring study, some of which would require considerable capital expenditures. Let me assure you that it is our intention to liaise closely with our United States colleagues so as to minimize duplication of efforts with the resultant waste of scarce and valuable resources.

Meanwhile we have already taken steps in two areas to allocate resources to this phase. First we have, in co-operation with Hydro Quebec, set up a joint technical committee to explore the areas of mutual concern relating to the combined use, by navigation and power, of the Beauharnois Canal during the ice formation and break-up periods.

Some of the items being actively explored are:

- *use of longitudinal ice booms to isolate the navigation channel from the hydro channel*
- *automatic boom opening and closing devices; and means of installing permanent anchors for ice booms*
- *possibility of installing permanent ice control structures.*

In a similar manner, discussions have been and will continue to be held from time to time as appropriate between the Seaway Authority, Development Corporation and Hydro on matters of mutual concern relating to the ice boom installations in the International section of the St. Lawrence River and the Niagara River.

The second action program relates to the substantial expansion, during the past winter, of our ice data collection information system. The program is broken into two distinct parts. Part one is the collection of information on the freeze-up, winter months and break-up periods in the Montreal-Lake Ontario section. The second part covers the *N.B. MCLEAN* experimental program during the past winter in the Lake Erie-Lake St. Clair area.

The Montreal-Lake Ontario data gathering system has actually two objectives: first to obtain base data which can be used in studies to determine if accurate theoretical methods can be developed to forecast freeze-up and break-up; secondly, the collection of information on ice conditions on a year to year basis for comparison purposes. This comparison information was provided this year in our first Seaway Notice and in regular ice bulletins to the industry, the first of which was issued March 1,

1971. By March 15, it was indicated to the trade that the opening would possibly be delayed by at least a week. The issuance of this up-to-date information also allows the industry to arrive at an independent judgment as to the feasibility of opening on the announced date.

The *N.B. MCLEAN* program was designed to obtain an appreciation of some of the problems which would exist with winter navigation in the Great Lakes. In retrospect, I must say that if we had ordered a "*tough*" winter in which to carry out the trials, we could not have had more ideal conditions.

In support of the probes carried out by the *N.B. MCLEAN* during the winter throughout Lake Erie, Detroit River and Lake St. Clair, there were regular ice reconnaissance flights, shore-based observation teams and helicopter "*close-in*" ice measurement readings.

Various other government agencies were consulted and participated in formulating and developing the winter operation for the *MCLEAN*. These included besides the Marine Administration; External Affairs, Fisheries & Forestry soon to become our new Department of the Environment, Canadian Meteorological Services, Canadian Hydrographic Service and Ontario Hydro. In addition, of course, the pertinent U.S. agencies such as the Department of Transportation, Saint Lawrence Seaway Development Corporation, Coast Guard and Corps of Engineers were also fully apprised of the program.

Ice and snow conditions, water quality, meteorological data and ice characteristics were recorded and the information is now being evaluated by the agencies concerned. During the mid-winter ice covered most of the lake. The prevailing winds from the west - often of gale force and gusting to 100 mph - caused heavy ridging and rafting of ice from the middle of the lake to the eastern end of the entrance to the Niagara River. Many ridges were 50 - 100 feet in width and up to 15 to 20 feet in height above water level. This heavy accumulation of ice was still evident at the end of March resulting in delays to the ships that were hoping to transit through the area, a condition which unfortunately persisted into the early days of May. It is indeed fortunate that the *MCLEAN* was stationed in the area otherwise the length of delay could have been significantly longer.

On the Welland Canal itself the problems are similar to those on the St. Lawrence. However, due to its location and milder climate, the problems tend to be less severe. The most significant of these as you have just seen is the ice conditions in the eastern end of Lake Erie. In 1970 the canal remained in operation until December 29 and could have remained open for some further period of time had user demand warranted it. However, it is estimated that the additional cost for each day the canal was kept open last year after the 22nd of December, was approximately $10,000., hence the need to have sufficient user demand to warrant keeping the system operational. It should be noted, however, that the canal construction was completed in 1932 and is essentially a single lock system. Therefore the programming of maintenance for the system will be a significant factor in any planning for a season extension.

Another aspect that will play a major role when an extension to the navigation season is discussed is *aids to navigation*. At present the Ministry of Transport is continuing with a program of improving the aids to navigation system as advances are achieved in the state-of-the-art. These improvements such as the automation of light stations, the replacing of floating aids with more reliable fixed pier lights, the installation of range lights and special radio beacons, are all designed to improve the capability of vessels to transit during reduced visibility conditions which are all too prevalent at the opening and closing of the existing navigation season.

The Ministry however recognizes the need to improve the effectiveness of the system and is therefore actively evaluating and experimenting with a number of accurate vessel location systems. Certainly a key in the development of any vessel location system will be the need to have an effective Marine Traffic Control and Information System. In our opinion, we consider the existing control systems meet today's requirements for dissemination of information such as the installation at St. Lambert, Quebec, which covers the area from Montreal to Lake Ontario, and the centre at St. Catharines, Ontario, which covers Lake Ontario, Welland Canal, and the eastern portion of Lake Erie. These two centres are in turn connected to the Ministry's traffic information and control centres at Montreal and Quebec City. However, to meet the further requirements an upgrading of the control system will be necessary. A first step in this upgrading is certainly the installation of peripheral VHF radio coverage throughout the Great Lakes. It is

hoped that the next step will be the introduction of an integrated U.S.-Canadian on-line real time computer assisted traffic control system from Montreal to the Lakehead.

Although year-round navigation does not appear to be feasible in the near future, Canada considers that the potential benefits likley to result from even a short extension of the navigation season on the Great Lakes are significant enough to justify the allocation of additional resources towards further research in this area.

Efforts towards further extension will most likely be concentrated on the end of the season rather than on an earlier opening. Severe ice conditions in the spring, combined with the necessity of protecting the hydro-electric installations located close to navigation channels would require heavy expenditures for icebreakers and protecting booms near power plants. On the other hand, late navigation seems to offer better potential economies since many shippers are in a rush to avoid heavy inventories over the winter months.

Benefits from any extension to the season can be subdivided into internal and external economies.

Internally, if new traffic is generated by an extension of the navigation season, the Seaway Entities would be the first to benefit, mainly through additional tolls and lockage fees. Overseas cargo, including grains to be transshipped at lower St. Lawrence ports, represents the traffic that would most likely register the largest increase. The fact that grain is harvested

in the fall would probably result in a more than proportionate increase in grain traffic since there usually is an urgent necessity to ship as much grain as possible before ice formation ends navigation in the Great Lakes.

Another important consideration for the Seaway would be the creation of increased capacity generated by a longer navigation season. If and when a stage is reached where the only possible improvement is the construction of new facilities, then the creation of additional capacity would presumably be an economical alternative. Any delay in beginning new construction would represent large savings in interest charges alone.

Economies would also result from a better utilization of the Ministry's national and commission ports, public harbours and government wharves. Both capital and manpower resources would become more productive. The benefits would primarily be concentrated in the area above Montreal but there would also be some in the area below Montreal.

Externally a better utilization of the vessels as well as of private harbours and wharves would affect the total cost of transportation and could lead to a reduction of seasonal unemployment in all related activities. Benefits resulting from a reduction in inventory levels are also considered to be an important factor. Bulk commodities such as coal and iron ore will benefit most from a longer season. In addition to savings on the interest costs of the capital tied up in stockpiles, capital savings on storage installations could also be realized in the long run.

Major benefits in terms of attracting new general cargoes are generally considered to require year-round navigation. Minor benefits, however, might be expected from additional trips of overseas ships into the Great Lakes as a result of lengthening of the season.

The multiplier effects of the above benefits would add considerably to the total benefits, however, these have not been considered.

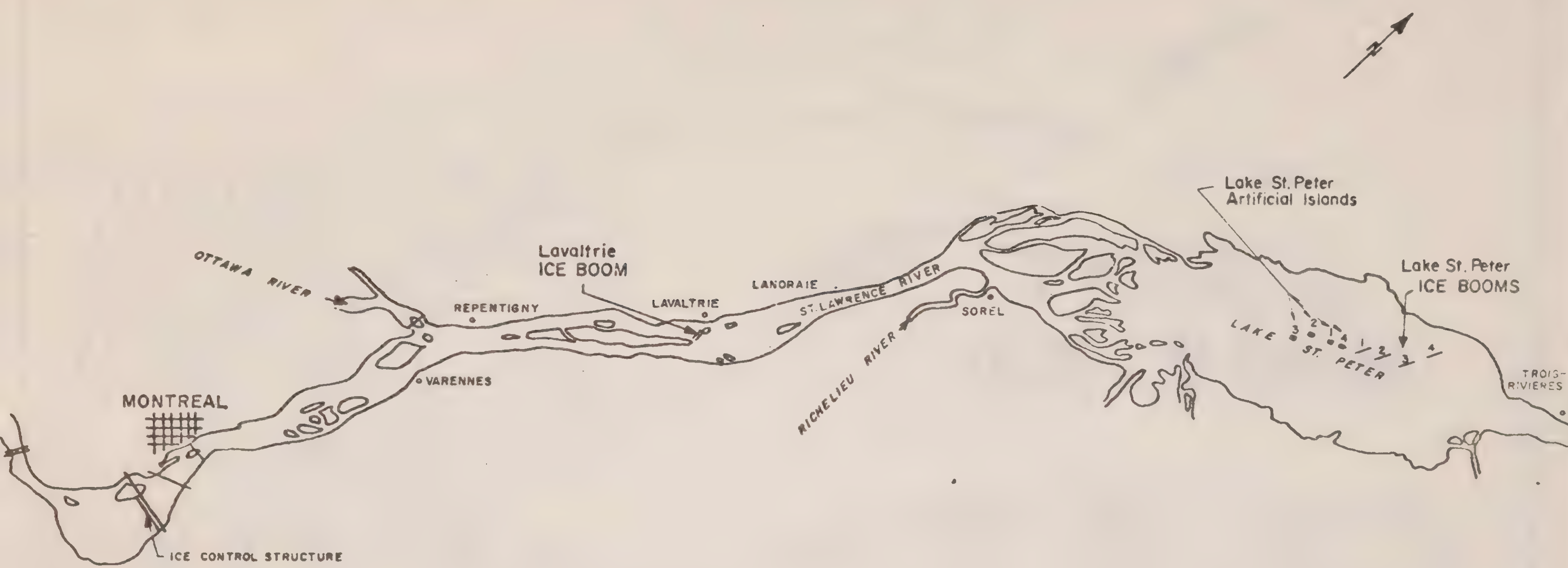
At this point in time, it is still extremely difficult to identify and estimate with any degree of accuracy the many different costs that may arise in addition to those already incurred for the program in the area from the Gulf of the St. Lawrence to the Great Lakes.

It is obvious, I am sure, that Canada is extremely interested in a further extension to the navigation season, particularly in view of the billions of dollars of capital works which have been constructed and are maintained in the Great Lakes-St. Lawrence River area. In the light of these interests the Ministry has designated a number of senior officials as the nucleus of a study group to examine the problems associated with a season extension and further develop Canada's policy in this field. This group will continue to work closely with the United States Department of Transportation to minimize duplication of efforts and resources.

LIST OF CANADIAN COAST GUARD ICEBREAKERS

	H.P.
LOUIS S. ST. LAURENT	27,000
JOHN A. MACDONALD	15,000.
N.M. ROGERS	13,000
d'IBERVILLE	10,000
LABRADOR	10,000
JOHN CABOT	9,500
N.B. MCLEAN	6,500
SIR HUMPHREY GILBERT	4,250
J.E. BERNIER	4,250
SIR WILLIAM ALEXANDER	4,250
MONTCALM	4,000
WOLFE	4,000
GRIFFON	4,000
CAMSELL	4,000
ALEXANDER HENRY	3,500
TUPPER	2,900
SIMON FRASER	2,900
NARWAL	2,500
WALTER E. FOSTER	2,000
THOMAS CARLETON	2,000
MONTMORENCY	2,000
SIMCOE	2,000
ERNEST LAPOINTE	2,000
TRACY	2,000
BARTLETT	1,750
PROVO WALLIS	1,750
TOTAL H.P.	147,850

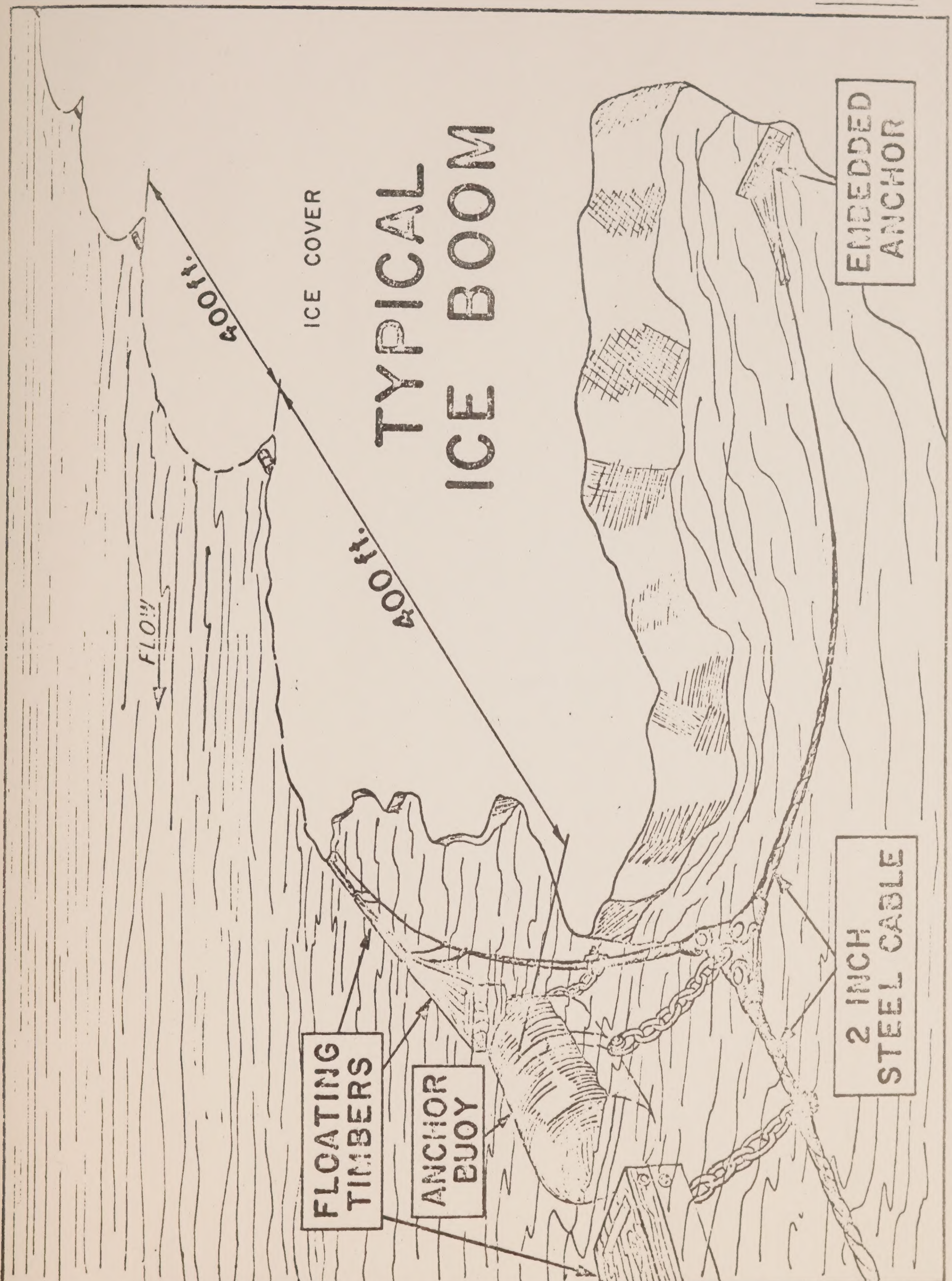
PLATE #2



MINISTRY OF TRANSPORT

ST. LAWRENCE RIVER

LOCATION OF ICE BOOMS LAVALTRIE AND LAKE ST. PETER
AND ARTIFICIAL ISLANDS LAKE ST. PETER


TYPICAL
ICE BOOM
ICE COVER
400 ft.
400 ft.
FLOW
FLOATING
TIMBERS
ANCHOR
BUOY
2 INCH
STEEL CABLE
EMBEDDED
ANCHOR